Machine-to-Machine Model for Water Resource Sharing in Smart Cities

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Abstract. Nowadays, level of natural resources exploitation is more complex regarding both quantity and quantity perspectives, therefore the concern for reducing waste and caring about environmental impact has raised proportionally. Water represents an essential resource for people needs, but also for industry and agriculture. This makes it a priority when it comes to finding innovative methods for its efficient usage. Improving cloud schemes, remodeling IoT applications and integrating different systems that were once thought to work independently are steps forward toward interoperability in Water Management. This paper discusses the current initiatives in water management, building an image on what needs are being served, what small or big solutions are being implemented. The model proposed is a solution for the management of a specific scenario using existing tools which need to be integrated.

Keywords: machine-to-machine · water · resource management.

1 Introduction

Along the last decades, our cities have been drastically changing, following up on the peoples needs with technology aid and with infrastructure remodeling. Natural resources exploit level has become more complex regarding both quantity and quantity perspectives, therefore the concern for reducing waste and caring about environmental impact has raised proportionally. Water is an every-day-life essential resource for basic people needs, but also industries and agriculture which makes it a priority when it comes to finding innovative methods for its proper management. Population being on a rise, but water being a limited resource, several issues are a matter of present public discussion: water quality, water waste, water-related natural disasters.

Domestic water supplies depend directly on the quality of water which has to have a tolerable level of risk, otherwise influencing negatively consumption, hygiene, food preparation and therefore public health. This calls for a permanent monitoring of water quality and a continuous improvement on water filtering.

Taking into consideration the threat of water shortages, another high priority would be reducing leakage (known as Non-Revenue Water) in water piping systems. These leakages consist of clean water which is lost before reaching its customer/consumer and which can happen because of a non-detected in time fractured pipe. Up to 40% of safe and clean water is lost because of leakages [1] in big cities. The ageing water infrastructure is very often prone to defects. Although large diameter pipes are expensive to replace, the risk of rupture and further massive water leakage is very high. By monitoring pressure, flow volume, direction and other conditions from within the city water networks (in more than a few key points situated kilometers away), actions can be taken before actual damage occurs and a better understanding of the water network will be provided.

Weather hazards that provoke natural disasters are 90% related [1] to water management issues. Sewerage city systems and water supplies need to be properly handled in order to avoid negative consequences which have more than once led to loss of life, damage of properties and infrastructure, human health issues. Preparation through collection and analysis of forecast information, relevant weather patterns, seismic activity or climate change indicators is an essential part of modern water management requirements.

The most common natural disaster encountered in Europe is represented by floods (EEA,2015). Usually, flooding occurs as a combination of phenomena and the risk of it having negative impact is amplified by the unsustainable urban/rural drainage systems. Mitigation against floods cannot be efficient without a water management system which takes into consideration water cycles, land planning integration with water factors, climate change and weather conditions. New sustainable drainage systems and management techniques are being developed and implemented trying to promote these planning practices to all levels of government and industry, showing the benefits that these will have on both the environment and the communities.

Smart Environments grow out of the continuous integration of ICT (Information and communications technology) with every-day needs or with large-scale remodeling needs. This new arrival can provide water management field a variety of architecture models in which data analysis results can be an essential support in decisions and actions of stakeholders,environmental associations or simply residents. SCADA technologies which have been supporting business processes related to water industries are not enough in order to properly solve the water sustainability problem. Real-time data management or GIS (Geographical Information Systems) integrations are concepts which define new product/service design in water management area. Remote monitoring, along with real-time diagnosis over report generation can optimize strategies of water distribution, water waste minimization or water quality conservation.

The aim of this paper is to research and summarize the current initiatives in water management, to present the technologies used in the development and implementation of these initiatives and to propose a solution for a small-scale water management problem or an improvement of an already running water management technology.

2 Current stage of development in the field

2.1 EOMORES project Copernicus platform

Earth Observation-Based Services For Monitoring And Reporting Of Ecological Status (EOMORES) and is a water quality monitoring project initiated in 2017 by a group of researchers who were previously involved in different smaller initiatives of water quality data gathering such as FRESHMON (FP7, 2010-2013), GLaSS (FP7, 2013-2016), CoBiOS (FP7, 2011-2013), GLoboLakes (UK NERC, 2012-2018), INFORM (FP7, 2014-2017). Many of these projects were funded by the European Unions Seventh Framework Programme for Research and Technological Development (FP7) and dealt with satelite data analysis in the monitoring of quality requirements imposed by the EU directives. The purpose of EOMORES project is different scale monitoring on water bodies, combining a series of techniques in order to obtain comprehensive results which can pe further used in an efficient manner.

The first technique is based on satellite monitoring and is providing a set of data from Copernicus Sentinels every few days, depending on the availability of the Sentinels, or the weather conditions. The data provided is then converted into information by one or several algorithms which have been previously tested against a wide range of factor (location, type of water, sensor technical characteristics). For the project research, EOMORES is collaborating with six countries (Italy, France, The Netherlands, the UK, Estonia, Lithuania and Finland), having different latitude coordinates for their location and also belonging to very different climates/ecoregions.

The main focus of the observations was the comparison of different approaches to atmospheric correction (the process of removing the effects of the atmosphere on the reflectance values of images taken by satellite or airborne sensors [2]). Satellite data has the advantage of covering large areas, but the drawback is that they have limited levels of detail achievement and measurement frequency. EOMORES uses Sentinel-1, Sentinel-2 and Sentinel-3 from Copernicus programme which offers free and open data. The first launch of Earth Observation satellites for Copernicus happened in 2014 and one year after, they have improved their assets by launching Sentinel-2A which was aimed to provide color vision data for changes on the surface of the Earth [2]. This mean that its optical system included three spectral bands in the electromagnetic spectrum area also called red-edge in which the difference is plant reflectance (visible light absorbed by plants versus radiation scattered in the photosynthesis).

The second technique consists of in situ observations or in situ monitoring which provides continuous measurements of a specific location in an assigned period of time (e.g 24 hours). This is information collected directly on site and is meant to be complementary or validating of the satellite data. As this kind of observations is not influenced so much of the weather state, the level of control over the frequency of measurement is higher. EOMORES researchers use hand-held devices for in situ data collecting, but an autonomous fixed-position optical instrument is in development as an improvement of the current Water Insight Spectrometer (WISP). This instrument is used for measuring Chlorophyll, Phycocyanin and Suspended sediments which are measures of algal biomass/cyanobacterial biomass/total suspended matter(TSM) [3]. The measured values appear on the display in 30-90 seconds. The raw information can be uploaded from the WISP to a cloud-platform for further analysis, model generation and further computation. The WISP has incorporated three cameras which are able to break light into its spectral components. By comparing the three sources which measure light coming straight into the WISP and the light reflected from the surface of the water, a derivation of the parameters wanted is being done through band-ratio algorithms.

The third technique is modelling which combines the results obtained through the two techniques previously presented in order to generate prediction data, forecast information on the specified area.

All the reliable quality water datasets are to be transformed in sustainable commercial services offered to international or national/regional authorities which are in charge of monitoring water quality or are responsible with water management and environmental reporting. Private entities that deal with the same monitoring issues can benefit from the data collected and mined by the EUMORES researchers.

2.2 AquaWatch project

AquaWatch project (2017-2019) is part of the GEO (Group on Earth Observation) Water Quality Initiative whose aim is to build a global water quality information service. The implementation of the project, currently in progress, is based on activity distribution across working groups, each with a specific focus element.

AquaWatch has a targeted public which consists of science and industrial communities, Non-Governmental Organizations, policy maker, environmental organization managers, non-profit organizations. Also, access to information will be promoted to simple recreational users too. These potential end-users are to be attracted and involved as volunteers in the working groups or for gathering data. In the beginning of 2018, a first group of products should be finished. This group would contain products which support turbidity measurement using different techniques:

- a Secchi disk [4] depth product which is a plain, circular disk 30 cm diameter for measurement of water transparency or turbidity in bodies in water;
- a diffuse attenuation coefficient product;
- a Nephelometric Turbidity Unit product;
- a surface reflectance product.

2.3 SmartWater4Europe project

Smart Water For Europe is a demonstration project that is being created to produce business cases for Smart Water Networks (SWN). Founded by the European

Union, the project will try to demonstrate optimal water networks and will look at the potential to integrate new smart water technologies across Europe. 21 European organizations are taking part in the project and four demonstration sites are available -Vitens (the Netherlands), Acciona (Spain), Thames (UK), Lille (France).

The project will help to understand how small technologies can deliver cost-effective performance and improve the water supply service given to customers. Smart water technologies and hi-tech informatics will allow the early detection of leaks on a 24/7 basis leading towards Smart Networks through data capture, analysis and reporting. As well as leakage detection, service excellence will be supported with best practices as energy monitoring, water quality and customer engagement. The main idea of the project is to implement small projects, receive recommendations based on the implementation and then go on with another small project in a different location, across Europe and beyond.

Vitens Inovation Playground (The Netherlands) is a demonstration site which consists of 2300 km of distribution network, serving around 200.000 households. Conductivity, temperature, chlornation level are measured using hi-tech sensors. Pipe burst detection and water hammer detection is tested through Syrinix sensors. Using an integral ICT solution, all the dynamic data from sensors, but also static data formats such as area photos, distribution network plans or soil maps, are stored and made available for water companies participating in the project and for researchers. The Vitens Inovation Playground serves also as a training facility in which operators learn how to respond to high risk incidents like contamination or massive leakages.

Smart Water Innovation Network in the city of BurGos (Spain) is working with three different hydraulic sectors (one industrial, one urban and one residential) which have been converted into one Smart Water Network. To create it, a network of quality sensors and conventional water meters with electronic versions equipped with communication devices have been installed. The information provided by the sector flow meters is integrated into the end-to-end management system, the so-called Business Intelligence Platform. This platform, hosted in the Big Data Center manages and processes the data gathered from common management systems, integrating also the algorithms developed in order to automatically detect leaks, predict consumption levels and check the quality of the water at any moment. The platform information is also used for continuously improving the overall service. The ultimate objective is to find the key parameters of the smart supply network so that the service could be implemented in any location, regardless of its characteristics. Among the benefits of such projects is the chance of savings of millions of dollars all over the world.

Thames Water Demo Site (The Netherlands) focuses on trunk mains leak detection by being aware of transients or rapid changes in pipe pressure and taking proactive action about the specific incidents. In addition, a first attempt has been made to distinguish between customer side leakage and wastage through a scalable algorithm which has been trained on smart meter data. In order to promote good practices, customers have been given incentives to save money and earn discounts by using water more carefully. An energy visualization tool was built in order to show where the energy on the network is being distributed. This graphic tool helps users better understand the dependency between demand, pressure and energy. All the solutions are concentrated in a single interface in order to display relevant information for operators to act or to discover cause-effect connections.

2.4 OPC UA with MEGA model architecture

The authors of [5] identify the problem of interoperability in water management initiatives, caused by the lack of support and lack of standardization in the monitoring processes, as well as the control equipment. They propose a smart water management model which combines Internet of Things technologies and business coordination for having better outcomes in decision support systems. Their model is based on the OPC US (Object Linking and Embedding for Process Control Unified Architecture) which is an independent platform that offers service-oriented possibilities of architecture schemes for controlling processes which are part of the manufacturing or logistic fields. The platform is based on web service technologies, therefore being more flexible to scenarios of usage.

The proposed model is MEGA model which takes into consideration functional decoupled architectures in order to achieve the goal of increased interoperability between the water management solutions on which companies and organizations are currently working. This would also solve the problem of SME (Small and Medium-sized Enterprise) companies locally oriented which provide good local solutions for water management, but which have difficulties in expanding to other countries, regions, or to maintain their funding on a long-term.

The MEGA architecture consists of several layers, the main ones being the following:

- Management and Exploitation layer hosts the main applications and services (can be executed in cloud, on local hosts) and supports the management definitions of the processes;
- Coordination layer defines and can associate, if necessary, entities to physical objects, collects the procedures defined by the ME layer and delivers them to the Subsystem layer after associating sequence of activities to them (recipes);
- Subsystem layer contains the subsystems that execute, independently or not, the procedures and recipes defined in the Coordination layer;
- Administration layer provides a user interface for administration and monitoring, enables configuration of entities defined in previous layers.

The water management model proposed includes a Physical Model and a Process Model which contain several Process Cells, Units, Units Procedures, Control Modules, Equipment Modules and Operations which can be handled differently, according to the business requirements. The big steps of the whole Mega Model process are as follows:

- Identifiers Mapping map recipe identifier to subsystem identifier(if the recipe is already provided, if not, translate the instructions into a standard recipe first);
- Recipe validation check if the subsystem is able to execute the process contained in the recipe;
- Process transfer to the suitable subsystem each subsystem receives its sequence of activities to be executed;
- Control and monitoring of the process execution information about the on going processes can be monitored in real-time.

2.5 WATER-M project

WATER-M project is an international initiative of representatives from four countries (Finland, France, Romania and Turkey), part of the Smart City challenge. The project is meant to contribute to a major upgrade of the water industry by helping with the introduction and integration of novel concepts such as GIS (Geographic Information System) usage, ICT with IoT applications or real-time data management or monitoring. The final purpose is to build a unified water business model targeted at European Union water stakeholders. Through operational control and monitoring real-time data, the WATER-M project is currently developing a service-oriented approach and event driven mechanisms for dealing with the water sustainability problem.

As the project was started in 2017, the plans and results are made public once progress is made. The use cases defined for this initiative are stated below [6]:

- Leak Detection;
- Development of Water Management and Flood Risk Prevention Platform;
- River Tele-monitoring;
- Performance monitoring of water distribution network;
- Control and optimization of the water distribution network;
- Coordinated management of networks and sanitation structures;
- New redox monitoring;
- Urban Farming.

Energy cost reduction and compatibility with European directives on water for allowing new business models for water management to emerge on the basic structure of the WATER-M are taken into consideration. Critical challenges, as well as options for various communication protocols such as LTE-M or LoRa, or AMR (Automatic Meter Reading) technologies with benefits and drawbacks were discussed in a state-of-the art [7] aimed at evaluating the previous proposals in the areas of water management. A new model has not yet been proposed, it is still work in progress.

3 Smart city water management available technologies

3.1 GIS (Geographic Information System)

A GIS system can be viewed as a database, which comprises all geometric elements of the geographical space with specific geometric accuracy together with information i. e. in tabular form which is related to geographic location. The GIS is associated by a set of tools, which do data management, processing, analysis and presentation of results for information and related geographic locations. The geographical space can be viewed as composed of overlaid planes of information over a wider geographical area and each plane has specific information or features [8].

The different planes contain similar geographic features. For example, one plane has elevations, another plane can have the drainage features represented, while another can have the rainfall. Thematic maps are then created, using map algebra on plane information [15], [16], [17],.

All the features in GIS are viewed as objects which can further be used to build models. The simplest object is a point object, than the complex/composed objects such as lines or areas rely on the point objects.

The up-to-date GIS technology is able to use data stored in warehouses or databases,accessing it through internet and running the GIS system every time the specific datasets change. This is a feature usually used in order to have reliable real-time hydrological models for forecasting systems. Further developments on GIS technology is aimed at integrating object oriented programming techniques, therefore ordering components into classes. An example of a component may be a line segment of a river and the data contained in such a class can represent coordinates, length values, profile dimentions or procedures for computing the river flow at a specific moment.

Water management could use GIS systems for basic data such as creating a national hydrology dataset which is permanently updated, but also for hydrologic derivatives which can be used together with satellite data and in situ information for dealing with prevention, management of water shortage or better organizing cities and rural areas.

3.2 IBM Water Management Platform

IBM Water Management Platform is a Big Data Cloud platform offered by IBM for implementation of solutions which can help end-users or organizations in several forms, regarding environmental or direct water problems. The set of features offered by the problem can be summarized in : - provide situational awareness of operations - integrate data from almost any kind of source (GIS, ERP-Enterprise Resource Planning, satellite, on site data-photo, video, numerical) - form patterns and correlations, visualize graphically contextual relationships between systems - run and monitor SOPs(Standard Operation Procedures) from dashboards - no compatibility adjustments needed when adding or removing devices - set up business rules for generating alerts in risky situations - compare current and historical data to discover patterns or cause-effect relations

IBM Intelligent Water solutions offer multiple deployment models to provide options for cities of all sizes with varying levels of IT resources. Cities with robust IT capabilities or strong interests in behind-the-firewall implementation can deploy this solution in their own data centers. Alternatively, deploying IBM

Intelligent Water on the IBM SmartCloud can help cities capitalize on the latest technology advances while controlling costs [9].

Also, the personalized views are used by different so called role-given-users for efficient analysis. The platform offers Citizen View (for water track usage in households), Operator View (for events, assets on geospatial maps), Supervisor View (for trends against KPI-key performance indicators) and Executive View (tracking and communicating KPI updates).

IBM Intelligent Water products are currently used in the Digital Delta system in the Netherlands which analyses data in order to forecast and prevent floods in the country, while the city of Dubuque (United States) uses the IBM platform for sustainable solutions in household water consumption, monitoring infrastructure leakages and reducing water waste.

3.3 TEMBOO platform -IoT Applications

Temboo is a software toolkit available directly from the web browser which enables anyone to access hard technologies like APIs(Application Programming Interfaces) and IoT(Intrnet of Things). Temboo users have access to data through public and private APIs and can develop their own IoT applications, starting from the services offered by the platform.

Developers would use what Temboo calls choreos to build together an application that is triggered from inputs registering on the IoT ARTIK device. Choreos are built out of APIs and act like microservices that perform one specific function that might be made available through an API. By splitting an APIs functionalities into microservices using the choreos format, code snippets can be kept short and reduce memory requirements and processing power on the device itself, while also enabling more complex server-side processing to be undertaken in the cloud [10]. Hardware development kits, embedded chipsets, sensors and data from sensors, actuators and remote control of actuators, M2M communication frameworks, and gateway/edge architectures can be integrated into Temboo. It generates editable pieces of software code which is in a standardized form, partitioned in production-ready blocks, easy to implement with the aid of cloud services.

Temboo offers lightweight SDKs, libraries, and small-footprint agents for programming every component : MCUs (C SDK/Library, Java Embedded (in progress)), SoCs/gateways (Python Agent with MCU, Java Agent with MCU, Python SDK, Java SDK), Mobile Applications (iOS SDK, Android SDK, Javascript SDK). For connecting devices to the cloud services, Temboo supports BlueTooth, Ethernet, WiFi and GSM(in progress).

Temboo can generate code for complete multi-device application scenarios, in which edge devices use a common IoT communications protocol to send Temboo requests through a gateway. The gateway handles all communication with Temboo, enabling local edge devices to interact with the huge range of web-based resources supported by Temboo [11]. The protocols used for M2M (Machine to Machine) communications are MQTT, CoAP or HTTP.

Message Queuing Telemetry Transport(MQTT) is an standard for publish-subscribe-based messaging protocols. It works on top of the TCP/IP protocol and is used for connections with remote locations with constaints for network bandwidth [12].

Constrained Application Protocol (CoAP) [13] is a service layer protocol well-suited internet devices, such as wireless sensor network nodes which are resource limited. This protocol enables nodes to communicate through Internet using similar protocols.It is also used with other mechanisms, like SMS on mobile communication networks.

A series of pre-build applications are provided which are demonstrated on a small scale, but can be also used for large scale problem. One of those applications is a Water Management for monitoring and remotely controlling the water level in a tank. This includes a mobile alert send to the user in case of action needed to be taken on the water tank level.

3.4 RoboMQ

RoboMQ is a Message Queue as Service platform hosted on cloud and also available as an Enterprise hosting option. This Software as a Service(SaaS) platform is an integrated message queue hub, analytics engine, management console, dashboard and monitoring & alerts; all managed and hosted in a secure, reliable and redundant infrastructure" [14].

The key features that the platform offers are : - Scalability (auto-scalable through any load balancing and scaling) - Expandability (it can be integrated in application or other features/functions can be added to it) - Reliability (messages are persistant and durable) - Monitoring through dashboards, analytic tools and specific alerts - Compatible with different protocols (MQTT, AMQP(Advanced Message Queueing Protocol), STOMP(Simple Text Oriented Messaging Protocol), HTTP/REST) - Support for multiple programming languages (all the libraries supporting the protocols above are supported by RoboMQ e.g Phyton, Java, .NET) - Secured connections (supports SSL (secure socket layer) connection for all available protocols)

RoboMQ acts as a message broker, managing queues between a producer and a consumer. Given its expandability feature, it has been integrated in an IoT Analytics application which collects data from various sensors, sends it to the queues managed by RoboMQ. The data is redirectioned to a IoT listener which then writes in a specific real-time database. All the data can be monitored through dashboards, panel metrics and graphs in real-time.

RoboMQ provides M2M integration through an open standard based platform to connect devices and sensors to the back-end applications, systems or processes. The protocols supported by RoboMQ (MQTT, STOMP, AMQP) can run on very small footprint devices using one of the languages that are supported by the device OS and profile. Among the devices that can be used are: Raspberry Pi, Audrino, Beaglebone and mBed based platforms. These devices will have the role of producer, sending the data as messages through to the RoboMQ broker, while the consumer will be the RoboMq dashboard application.

4 Proposed model and possible directions

Taking into consideration the possibilities offered by the ICT technologies and the critical problems in water management field, a model of M2M device collaboration is proposed. The main purpose is optimization of water resource sharing. This model represents a M2M integration between RoboMQ (messsage broker) and Temboo (IoT software toolkit) to coordinate the distribution of the same available water resource when several requests are made at the same time. We use the following methods:

- Use labeled queues to differentiate between messages (data values), therefore evaluating the greater need before sending the commands to the actuators;
- Tune prameters for obtaining a generic water saving mode which the user can set when receiving several notification alerts of water shortage (expand for usage on large scale-e.g. city scale) Targeted at/ Use Cases;
- Regular end-users for better management of household or small facilities water resources - farms, rural houses, residences with their own water supply, zoo/botanic gardens;
- Authorities for better management of single city water resources in critical situations- prolonged water shortage, prolonged repairs to the water infrastructure, natural disasters.

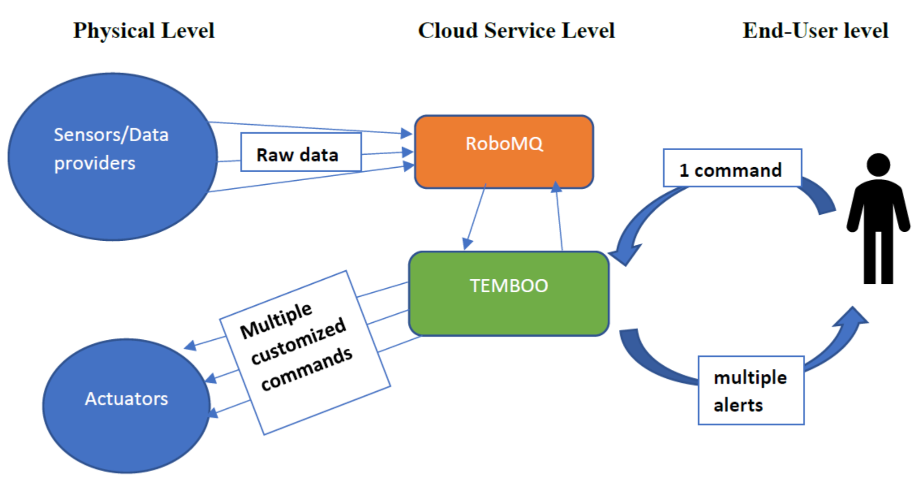

Fig. 1. Proposed architecture

The architecture of the proposed model in presented in Figure 4. The architecture is structured on three levels: Physical level, Cloud Service level and End-User level. At Physical level exist sensors that transmit raw data to a RoboMq service, and actuators that receive multiple customized commands form a TEMBOO service. Al Cloud Service leve exist two systems ROBOMQ that receive data from sennsors and TEMBO that send commands at physical level. The top level in End-User level that take as input commands form users and receive multiple alert form physical and cloud service level.

5 Conclusions

As smart cities emerge, new solutions are needed for every resource management our there. Water management is an area that needs solutions, both for regular basis usage and for critical situations. Since technology has become more and more sophisticated, but at the same time more user-friendly, opportunities for developing ideas with easy-to-understand tools have appeared.

Although on a large, up to global scale the focus is on standardization of water management processes and building business models that can be feasible regardless of the conditions/location, pilot solutions on local/little scale are the ones that support the larges research, through beneficial continuous small results or continuous tries. Improving cloud schemes, remodeling IoT applications and integrating different systems that were once thought to work independently are steps forward toward interoperability in Water Management.

This paper discussed the currently initiatives in water management, building an image on what needs are being served, what small or big solutions are being implemented. The model proposed is a solution for the management of a specific scenario using existing tools which need to be integrated. The second part of the paper will contain possibilities of implementation and case studies on the proposed model.

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References

1. GSMA Homepage, https://www.gsma.com/iot/wp-content/uploads/2016/11/Smart-water-management-guide-digital.pdf. Last accessed 7 Jan 2018
2. COPERNICUS Homepage, http://newsletter.copernicus.eu/issue-11-september-2015/article/launch-sentinel-2a-brings-colour-vision-copernicus-programme. Last accessed 7 Jan 2018
3. EOMORES-H2020 Homepage, http://eomores-h2020.eu/blog/what-is-a-wisp-anyway/. Last accessed 7 Jan 2018
4. Preisendorfer, R. W: Secchi disk science: Visual optics of natural waters1. Limnology and oceanography, 31(5), 909–926 (1986)

5. Robles, T., Alcarria, R., de Andrs, D. M., Navarro, M., Calero, R., Iglesias, S., & Lpez, M: An IoT based reference architecture for smart water management processes.JoWUA, 6(1), 4-23 (2015)
6. ITEA3 Homepage, https://goo.gl/CC61Q8. Last accessed 7 Jan 2018
7. Berhane Gebremedhin: SSmart Water Measurements: Literature Review. Water-M Project, June 13 2015
8. Hatzopoulos, John N. "Geographic information systems (GIS) in water management." Proceedings of the 3rd International Forum Integrated Water Management: The key to Sustainable Water Resources. 2002.
9. IBM Intelligent Water, infrastructure Services Documentation, IBM Industry Solutions-Solution Brief, https://www-935.ibm.com/services/multimedia/Intelligent_Water.pdf. Last accessed 7 Jan 2018
10. Mark Boys, Temboo API Platform Puts Industrial Iot in Reach, https://www.programmableweb.com/news/temboo-api-platform-puts-industrial-iot-reach-devs/analysis/2015/05/28. Last accessed 7 Jan 2018
11. TEMBOO Homepage, https://temboo.com/hardware/m2m-mqtt. Last accessed 7 Jan 2018
12. Hunkeler, Urs, Hong Linh Truong, and Andy Stanford-Clark. "MQTT-SA publish/subscribe protocol for Wireless Sensor Networks." Communication systems software and middleware and workshops, 2008. comsware 2008. 3rd international conference on. IEEE, 2008.
13. Shelby, Zach, Klaus Hartke, and Carsten Bormann. "The constrained application protocol (CoAP)." (2014).
14. ROBOMQ Homepage, https://robomq.readthedocs.io/en/latest/. Last accessed 7 Jan 2018
15. Gorgan, D., Bacu, V., Rodila, D., Pop, F., & Petcu, D. (2010). Experiments on ESIPEnvironment oriented satellite data processing platform. Earth Science Informatics, 3(4), 297-308.
16. Petcu, D., Zaharie, D., Gorgan, D., Pop, F., & Tudor, D. (2007, September). MedioGrid: a grid-based platform for satellite image processing. In Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, 2007. IDAACS 2007. 4th IEEE Workshop on (pp. 137-142). IEEE.
17. Pop, F. (2007, July). Distributed algorithm for change detection in satellite images for Grid Environments. In Parallel and Distributed Computing, 2007. ISPDC'07. Sixth International Symposium on (pp. 41-41). IEEE.